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Date of Application: June 13, 1994

Application Number: Japanese Patent Application

No.6-130301

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July 21, 1995

Commissioner,

Patent Office YUJI KIYOKAWA

(Seal)

Certificate No.07-3039904

6-130301

[Name of the Document]	Patent Application
[Reference No.]	2775006
[Date]	June 13, 1994
[Address to]	Commissioner of the Patent Office
[International Classification]	G02B 27/00
[Title of the Invention]	OBSERVATION OPTICAL SYSTEM
[Number of Claims]	13
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[Way of Payment]	Prepaid

[Prepayment Ledger No.] 011224

[Amount] 21000

[List of Filed Materials]

[Material]	Specification	1
[Material]	Drawings	1
[Material]	Abstract	1

[General Power of Attorney's No.] 9003707

[Proof Requirement] Required

[Name of the Document] Specification

[Title of the Invention] Observation Optical System

[What is claimed is:]

[Claim 1] An observation device, characterized by having an observation optical system for guiding the light of an original image to the eye of an observer through a reflection optical system, said reflection optical system including a curved surface functioning to totally reflect the light.

[Claim 2] An observation device according to claim 1, wherein said curved surface is positioned directly before the eye.

[Claim 3] An observation device according to claim 1 or claim 2, wherein said curved surface has a negative refractive power in the cross section in the meridian-line direction.

[Claim 4] An observation device according to claim 1, wherein said curved surface has a variable optical power depending on the azimuthal angle.

[Claim 5] An observation optical system for guiding a light of an original image to the eye,

characterized in that said light is caused to be totally reflected toward a direction away from the eye by a curved surface and the totally reflected light is caused to be reflected toward the eye side by a reflection surface and to be transmitted through said curved surface so as to be guided to the eye.

[Claim 6] An observation optical system according to claim 5, characterized by satisfying a condition $|\alpha| \leq 20°$ wherein α is the angle between the tangential line to said curved surface at the vertex thereof and a line perpendicular to the optical axis of the eye.

[Claim 7] An observation optical system according to claim 5, wherein said curved surface has a negative refractive power.

[Claim 8] An observation optical system according to claim 5, wherein said curved surface has a variable optical power depending on the azimuthal angle.

[Claim 9] An observation optical system according to claim 5, wherein said reflection surface has a variable optical power depending on the azimuthal angle.

[Claim 10] An observation optical system for guiding a light of an original image to the eye, characterized by guiding the light to the eye through a total reflection surface for totally reflecting said light and a reflection surface having a variable optical power depending on the azimuthal angle.

[Claim 11] An observation optical system according to claim 10, characterized by satisfying a condition $|\alpha| \leq 20°$ wherein α is the angle between the tangential line to said total reflection surface at the vertex thereof and a line perpendicular to the optical axis of the eye.

[Claim 12] An observation optical system according to claim 10, wherein said total reflection surface has a negative refractive power in the cross section in the meridian-line direction.

[Claim 13] An observation optical system according to claim 10, wherein said reflection surface has a variable optical power depending on the azimuthal angle.

[Detailed description of the Invention]

[0001]

[Field of the Industrial Utilization]

The present invention relates to an observation optical system, and more particularly to an optical system adapted for use in a device called head-up display or spectacle-type display.

[0002]

[Prior Art]

Conventionally there have been proposed display devices in which a cathode ray tube (CRT) or a liquid crystal display (LCD) is positioned close to the head of the observer whereby the observer is enabled to observe the image formed by such CRT or LCD, as disclosed for example in U.S. Patent Nos. 4,081,209 and 4,969,724 and Japanese Patent Laid-Open Application Nos. 58-78116, 2-297516 and 3-101709.

[0003]

Japanese Patent Laid-Open Application No. 3-101709 discloses an observation device providing a relatively easily observable real image by re-focusing an original image. However, a considerably large space is unavoidable because an optical lens is employed for re-imaging.

[0004]

On the other hand, U.S. Patent Nos. 4,081,209 and

4,969,972 and Japanese Patent Laid-Open Application Nos. 58-78116 and 2-297516 disclose observation devices designed to observe a virtual image which is advantageous for compactizing the device though it is somewhat inferior in the ease of observation.

[0005]

[Problems to be solved by the Invention]

Though the observation device of the latter type can achieve compactization in comparison with that of the real image type, the extent of such compactization cannot be said sufficient. Among the above-mentioned prior technologies, the one disclosed in the Japanese Patent Laid-Open Application No. 58-78116 is relatively advanced in terms of compactization, but the device still has a large thickness in the direction of the axis of the eye. It is also described that the observed image involves optical distortion, astigmatism and coma.

[0006]

In consideration of the foregoing, an object of the present invention is to provide a compact and thin observation optical system.

[0007]

Another object of the present invention is to provide an observation optical system with reduced

aberrations.

[0008]

In order to achieve the above-mentioned objects, the present invention characterized in that: in an observation optical system for guiding the light of an original image to the eye of the observer through a reflection optical system, the reflection optical system includes a curved surface having a function to totally reflect the light; or that in an observation optical system for guiding the light of an original image to the eye, the light is caused to be totally reflected at a curved surface toward a direction away from the eye, the light which has been totally reflected is reflected toward the eye side at a reflection surface, and the light is guided to the eye through the curved surface; or that in an observation optical system for guiding the light of an original image to the eye, the light is guided to the eye through a total reflection surface for totally reflecting the light and a reflection surface having a variable optical power depending on the azimuthal angle.

[0009]

Other characteristics of the present invention will be disclosed with reference to the embodiments

described below.

[0010]

[Embodiments]

At first there will be explained the basic principle of the display optical system of the present invention, with reference to Fig. 6. Display means 4, for displaying an original image such as a character or a pattern, is composed for example of a known liquid crystal display (LCD). There are also provided a first optical member 3a for guiding the light from the display means 4 to the eye of the observer, and a second optical member 3b. The light from the display means 4 at first enters the first optical member 3a, then totally reflected by a totally reflection surface 1, at the eye side, of the first optical member, further reflected by a concave half mirror 2, concave to the eye of the observer, transmitted by the above-mentioned total reflection surface 1 and guided to the eye.

[0011]

(A) and (B) in Fig. 1 illustrate the optical path, seen respectively from the top and from the side.

[0012]

Thus, the observer can observe the image on the display means 4, superimposed with the external

scenery. Although the present embodiment provides a superimposing device, there may also be provided a device for merely observing the image display, in which case the concave mirror is composed of a mirror.

[0013]

Owing to the above-explained configuration, the present and ensuing embodiments provide extremely thin, compact display devices, with a thickness of the optical system in the order of 10 to 15mm. Also there is achieved a wide viewing angle of ca. ±16.8° in the horizontal direction and ca. ±11.4° in the vertical direction.

[0014]

Such compactization, wide viewing angle and satisfactory optical performance are derived in the present embodiment from fact that a surface at the observer side is utilized as a total reflection surface and a transmitting surface, and that the concave mirror 2 is positioned considerably eccentric with respect to the optical axis of the eye. In addition there are significant contributions from facts that the total reflection surface is constituted by a curved surface, particularly with optical power variable depending on the azimuthal angle as will be shown in the following numerical examples, and that the concave mirror 2 is

given an optical power depending on the azimuthal angle.

[0015]

In particular, the optical power depending on the azimuthal angle, given to the concave mirror 2, allows to sufficiently eliminate the eccentric aberration resulting from the eccentric positioning thereof. Also the total reflection surface is similarly constituted by a curved surface to correct the aberrations generated by the concave mirror.

[0016]

In the following description, the folding direction of the light will be called the direction of generatrix, while a direction perpendicular thereto will be called the direction of meridian. In the present embodiment, the image angle is made wider in the meridian direction, and a relatively strong positive refractive power of the concave mirror generates aberrations, but the total reflection surface is given, in the cross section along the meridian direction, a negative optical power to correct such aberrations. Along the optical path in the cross section in the meridian direction from the side of the display device or the side of the eye of the observer, there are provided, in succession of a surface of a

negative refractive power, a surface of a positive refractive power (concave mirror) and a surface of a negative refractive power, so that the aberrations are easy to eliminate because of such symmetrical arrangement of the refractive powers.

[0017]

For reducing the thickness in the direction of optical axis of the eye, the elements are desirably so arranged that the optical system 3 stands upright. More specifically, referring to Fig. 7, there is preferably satisfied a condition:

$|\alpha| \leq 20°$

wherein α is the angle (tilt angle) of the tangential line to the total reflection surface 1 at the vertex thereof, to a line perpendicular to the optical axis of the eye. Outside this range, the optical system becomes thicker in the direction of the optical axis, whereby the device becomes bulkier. Also in case of superimposing an image on the scenery, the inclination of the optical member becomes larger to cause a distortion in the observed scenery.

[0018]

More preferably there is satisfied a condition:

$-15° \leq \alpha \leq 5°$

Below the lower limit, the optical system can be made

thinner in a direction parallel to the optical axis of the eye, but the distortion becomes severer. Above the upper limit, the optical system becomes thicker in a direction parallel to the optical axis of the eye, and the prisms become undesirably heavy.

[0019]

In the present embodiment, since the total reflection surface is concave to the eye, the light entrance face at the outside is constituted by a substantially same curved surface in order to prevent the distortion in the observed scenery.

[0020]

The concave mirror 2 is made considerably eccentric with respect to the optical axis of the eye, whereby an eccentric aberration is generated. However this eccentric aberration is satisfactorily corrected by constituting the total reflection surface with a curved surface and employing, in the concave mirror 2, a surface of which curvature varies depending on the azimuthal angle (toric or anamorphic surface). Preferably an aspherical surface (toric aspherical or anamorphic aspherical surface) is employed to attain an extremely satisfactory optical performances.

[0021]

With respect to the generatrix direction (y-

direction) which is the direction of folding of the light and the meridian direction perpendicular thereto, the faces of the optical system are so designed to have optical powers variable depending on the azimuthal angle, but, in the entire system, the paraxial focal length is preferably substantially constant in any direction. More specifically, there is preferably satisfied a condition:

$$0.9 < |f_y/f_x| < 1.1$$

wherein f_y and f_x are paraxial focal lengths of the entire system respectively along the cross section in the direction of generatrix and that in the direction of meridian.

[0022]

Also the total reflection surface (or transmitting surface) or the concave mirror is so designed, as explained in the foregoing, as to vary the optical power depending on the azimuthal angle thereby suppressing the eccentric aberration, and, for this purpose, there is preferably satisfied a condition:

$$|r_x| < |r_y|$$

wherein r_y and r_x are radii of paraxial curvature of said surface respectively in the cross section in the generatrix direction and in that in the meridian direction.

[0023]

In the present embodiment, for achieving compact configuration, the concave mirror 2 is significantly tilted (decentralized) in the direction of generatrix which is the direction of folding of the light, the eccentric aberration is generated larger in the direction of generatrix than in the direction of meridian. Thus the optical power in the cross section in the direction of generatrix is made weaker than that in the cross section in the direction of meridian, namely the radius of paraxial curvature is made longer in the direction of generatrix as indicated in the foregoing condition, thereby suppressing the eccentric aberration in the direction of generatrix.

[0024]

Preferably these curvatures are so selected as to satisfy:

$|r_x/r_y| < 0.85$

Outside this range, the eccentric aberration becomes conspicuously large.

[0025]

On the other hand, in case the entrance face 5 is so constructed as to have varying optical power depending on the azimuthal angle as in the following numerical examples 2 to 4, the eccentric aberration can

be suppressed by inversely satisfying a condition:

$$|r_x| > |r_y|$$

[0026]

For further satisfactory correction of aberrations, there are preferably satisfied conditions:

$$-2.0 < 2f_x/r_{x2} < -0.1 \quad \dots \text{(a)}$$

$$-2.5 < 2f_x/r_{x3} < -0.5 \quad \dots \text{(b)}$$

wherein r_{x2} and r_{x3} are radii of paraxial curvature respectively of the total reflection surface (or transmitting surface) 1 and the concave mirror 2, in the cross section in the meridian direction.

[0027]

Below the lower limit of the condition (a), the curvature (negative power) of the total reflection surface in the meridian direction becomes stronger and the correction of distortion becomes difficult. Also below the lower limit of the condition (b), the curvature (positive power) of the concave mirror in the meridian direction becomes strong and the correction of astigmatism becomes difficult. On the other hand, above the upper limit of the condition (a), the curvature of the total reflection surface in the meridian direction becomes to have a positive power, so that the total reflection condition becomes difficult to satisfy. Also above the upper limit of the

condition (b), the positive power of the concave mirror in the meridian direction becomes weaker, so that the thickness of the optical system in a direction parallel to the optical axis of the eye becomes undesirably large.

[0028]

Furthermore, there are preferably satisfied conditions:

$-1.0 < 2f_y/r_{y2} < 0$ ... (c)

$-2.5 < 2f_y/r_{y3} < -0.2$ ... (d)

wherein f_y is the focal length of the entire system in the generatrix direction, r_{y2} is the radius of curvature of the total reflection surface, and r_{y3} is the radius of curvature of the concave mirror.

[0029]

Below the lower limit of the condition (c), the negative power of the total reflection surface in the generatrix direction becomes stronger, so that the eccentric distortion becomes difficult to correct. Below the lower limit of the condition (d), the positive power of the concave mirror in the generatrix direction becomes stronger, thereby generating a large eccentric astigmatism. Also above the upper limit of the condition (c) relating to the total reflection condition in the generatrix direction, it becomes

difficult to satisfy the total reflection condition. Also above the upper limit of the condition (d) relating to the power of the concave mirror in the generatrix direction, this power becomes weaker so that the entire length of the optical system extends in the generatrix direction.

[0030]

In the foregoing, the structures of the total reflection surface (or transmitting surface) 1 and the concave mirror 2 have been explained in relation principally with the curvature, but, in the present embodiment, the concave mirror 2 is subjected to a parallel shift, in the direction of generatrix (y-direction), from the optical axis of the eye toward the original image side (+) as shown in Fig. 7, whereby the eccentric distortion in the generatrix direction can also be suppressed.

[0031]

The eccentric distortion can be suppressed by a parallel shift satisfying:

$E \geq 2.5$ mm

wherein E is the amount of the parallel shift or the distance from the optical axis of the eye to the vertex of the concave mirror surface in the direction of generatrix (cf. Fig. 7). In the following example 1,

this amount E of parallel shift is equal to 5.2 mm, but it may be selected larger as in other examples for satisfactorily correcting the aberrations, and preferably satisfied a condition $E \geq 23$ mm.

[0032]

Then, with respect to the entrance face 5, the angle β between the entrance face and the original image surface constituting the display means, in the direction of generatrix, is preferably so selected as to satisfy a condition:

$$5° \leq \beta \leq 30°$$

Below the lower limit, the entrance face and the original image surface become closer to parallel, so that the original image becomes undesirably thick in the direction parallel to the optical axis of the eye. On the other hand, above the upper limit, the original image becomes perpendicular to the direction parallel to the optical axis of the eye.

[0033]

The present embodiment assumes, though not illustrated, the use of a rear light source or direct natural light for illuminating the original image. If the original image becomes perpendicular to the above-mentioned optical axis, it becomes difficult to efficiently obtain natural light for direction

illumination and the virtual image obtained by the reflective optical system becomes darker. Consequently the present embodiment utilize the natural light illumination and the back light illumination selectively by detecting the external illumination intensity, thereby utilizing the natural light illumination in the daytime when the natural light is strong and the back light illumination at night.

[0034]

The display means 4 for forming the original image is composed of a liquid crystal display (LCD) device for compactizing the entire device, and the angle γ between the optical axis at the center of the original image and the principal ray of the light emerging from the original image (central light beam of the diaphragm constituted by the eye) (cf. Fig. 7) is preferably so selected as to satisfy:

$$|\gamma| \leq 10°$$

This condition is required in case a liquid crystal display device is employed for providing the original image. The liquid crystal display in general has a narrow viewing angle, the light obliquely entering the display device and emerging therefrom is easily lost. Therefore, a bright virtual image cannot be obtained unless the light is made to enter the liquid crystal

display surface and to emerge therefrom as perpendicularly as possible. The above-mentioned condition allows to observe a sufficiently bright image.

[0035]

Figs. 2 to 5 are optical cross-sectional views respectively of numerical examples 1, 2, 3, and 4 explained in the following. The configuration shown in Fig. 2 employs toric aspherical surfaces in the concave mirror and the total reflection surface. The configuration shown in Fig. 3 employs anamorphic aspherical surfaces in all of the concave mirror, total reflection surface and light entrance surface. Also the configurations shown in Figs. 4 and 5 employ anamorphic aspherical surfaces in all the optical surfaces.

[0036]

In the numerical examples 2 to 4 corresponding to Figs. 3 to 5, the entrance face 5 is also provided with a curvature for attaining more satisfactory correction of aberrations.

[0037]

In the present embodiment, all the optical members are composed of acrylic resin, but glass may naturally be employed instead.

[0038]

In the following there are shown numerical examples of the present embodiment, wherein TAL indicates a toric aspherical lens surface, and AAL indicates an anamorphic aspherical lens surface.

[0039]

The TAL is defined by:

[0040]

[Composed Font 1]

$$z=\frac{y^2/r_{yi}}{1+\sqrt{1-(1+k_i)\ (y/r_{yi})^2}}+A_iy^4+B_iy^6+C_iy^8+D_iy^{10}$$

wherein i indicates the surface number.

Also the AAL is defined by:

[0041]

[Composed Font 1]

$$z=\frac{y^2/r_{iy}+x^2/r_{ix}}{1+\sqrt{1-\{(1+k_{yi})\ (y/r_{yi})^2+(1+k_{xi})\ (x/r_{xi})^2\}}}$$

$$+AR_i\{(1+AP_i)y^2+(1-AP_i)x^2\}^2+BR_i\{(1+BP_i)y^2+(1-BP_i)x^2\}^3$$

$$+CR_i\{(1+CP_i)y^2+(1-CP_i)x^2\}^4+DR_i\{(1+DP_i)y^2+(1-DP_i)x^2\}^5$$

wherein i indicates the surface number.

[0042]

A_i, B_i... are aspherical coefficients.

[0043]

In the following examples, at least the total reflection surface is constructed with a surface with variable refractive power depending on the azimuthal angle, but it may also be constructed with a rotationally symmetrical spherical or aspherical surface.

[0044]

[Composed Font 3]

Example 1

	r_{yi}[mm] radius of curvature in generatrix direction	r_{xi}[mm] radius of curvature in meridian direction	y, z coordinates of vertex		tilt angle in generatrix direction	
i=1	∞		(0、0)		0	
2	-548.019	-74.077	(-0.05、19.80)	TAL	0	in prism
3	-57.595	-40.526	(5.10、29.14)	TAL	-22	in prism
4	-548.019	-74.077	(-0.05、19.80)	TAL	0	in prism
5	∞		(18.58、28.07)		68.90	in prism
6	∞		(21.38、29.15)		51.17	

	K_2、K_4	A_2、A_4	B_2、B_4	C_2、C_4	D_2、D_4
(TAL2、4)	613.869	-0.473E-5	0.326E-7	-0.940E-10	0.991E-13

	K_3	A_3	B_3	C_3	D_3
(TAL3)	-1.360	0.345E-5	-0.301E-7	0.944E-10	-0.113E-12

refractive index (d-line) of prism	1.49171	focal length in generatrix direction	f_y=21.07mm
Abbe's number (d-line) of prism	57.4	focal length in meridian direction	f_x=21.86mm

(numerical data)

$\alpha = -1.8°$

$|f_y/f_x| = 0.96$

$|r_x/r_y| = 0.7$

$2f_x/r_{x2} = -0.59$

$2f_x/r_{x3} = -1.08$

$2f_y/r_{y2} = -0.08$

$2f_y/r_{y3} = 0.73$

E= 5.2mm

$\gamma = 1.36$

$\beta = 17.7$

[0045]

[Composed Font 4]

Example 2

	r_{yi} [mm] radius of curvature in generatrix direction	r_{xi} [mm] radius of curvature in meridian direction	y, z coordinates of vertex		tilt angle in generatrix direction	
i=1	∞		(0、0)		0	
2	-2158.074	-32.224	(0.60、19.83)	AAL	-10.55	} in prism
3	-63.157	-32.870	(34.76、30.90)	AAL	15.81	} in prism
4	-2158.074	-32.224	(0.60、19.83)	AAL	-10.55	} in prism
5	72.108	1049.744	(14.82、29.00)	AAL	53.74	} in prism
6	∞		(17.03、30.62)		42.91	

(AAL2、4)	$K_{y2,4}$	$K_{x2,4}$	$AR_{2,4}$	$BR_{2,4}$	$CR_{2,4}$	$DR_{2,4}$
	-13763.5	-3.896	-0.170E-4	0.401E-7	-0.154E-9	0.223E-12
			$AP_{2,4}$	$BP_{2,4}$	$CP_{2,4}$	$DP_{2,4}$
			-0.245	0.416E-1	0.870E-1	0.203E-1
(AAL3)	K_{y3}	K_{x3}	AR_3	BR_3	CR_3	DR_3
	1.238	0.279	-0.317E-5	0.248E-8	-0.179E-11	0.608E-15
			AP_3	BP_3	CP_3	DP_3
			0.249	0.327E-2	-0.192E-1	0.181E-1
(AAL5)	K_{y5}	K_{x5}	AR_5	BR_5	CR_5	DR_5
	6.285	-1.33E-6	-0.114E-4	-0.402E-6	0.113E-8	-0.411E-10
			AP_5	BP_5	CP_5	DP_5
			0.273E1	0.155E1	0.160E1	-0.644

refractive index (d-line) of prism 1.49171

focal length in generatrix direction f_y=23.20mm

Abbe's number (d-line) of prism 57.4

focal length in meridian direction f_x=24.09mm

(numerical data)

α = -10.5°

$|f_y/f_x|$ = 0.96

$r_x|/r_y$ = 0.52

$2f_x/r_{x2}$ = -1.5

$2f_x/r_{x3}$ = -1.47

$2f_y/r_{y2}$ = -0.02

$2f_y/r_{y3}$ = -0.73

E= 34.1mm

γ = 0.23°

β = 10.8°

[0046]

[Composed Font 5]

Example 3

	r_{yi} [mm] radius of curvature in generatrix direction	r_{xi} [mm] radius of curvature in meridian direction	y, z coordinates of vertex		tilt angle in generatrix direction	
i=1	∞		(0、0)		0	
2	-3945.723	-49.792	(3.665、20.415)	AAL	0.04	in prism
3	-67.136	-38.803	(36.403、32.01)	AAL	14.60	in prism
4	-3945.723	-49.792	(3.665、20.415)	AAL	0.04	in prism
5	123.302	843.030	(19.610、28.357)	AAL	61.72	in prism
6	∞		(22.402、29.859)		52.54	

(AAL2、4)	$K_{y2,4}$	$K_{x2,4}$	$AR_{2,4}$	$BR_{2,4}$	$CR_{2,4}$	$DR_{2,4}$
	7202.73	-7.709	-0.142E-7	0.379E-7	-0.154E-9	0.198E-12
			$AP_{2,4}$	$BP_{2,4}$	$CP_{2,4}$	$DP_{2,4}$
			-0.183	0.710E-1	0.514E-1	0.201E-1
(AAL3)	K_{y3}	K_{x3}	AR_3	BR_3	CR_3	DR_4
	1.066	0.193	-0.222E-5	0.321E-8	-0.188E-11	0.461E-15
			AP_3	BP_3	CP_3	DP_3
			0.390	0.586E-1	-0.185E-1	-0.222E-1
(AAL5)	K_{y6}	K_{x5}	AR_6	CR_5	DR_5	
	-85.544	-916252	-0.913E-6	-0.204E-9	0.117E-13	-0.227E-10
			AP_5	BP_5	CP_6	DP_5
			0.989E1	0.128E1	0.128E2	-0.952E-1

refractive index (d-line) of prism 1.49171

focal length in generatrix direction f_y=23.71mm

Abbe's number (d-line) of prism 57.4

focal length in meridian direction f_x=23.70mm

(numerical data)

α = 0.05°

$|f_y/f_x|$ = 1.0

$|r_x/r_y|$ = 0.58

$2f_x/r_{x2}$ = -0.95

$2f_x/r_{x3}$ = -1.22

$2f_y/r_{y1}$ = -0.01

$2f_y/r_{y3}$ = -0.71

E = 25.6mm

γ = 1.97°

β = 15.5°

[0047]

[Composed Font 6]

Example 4

	r_{yi} [mm] radius of curvature in generatrix direction	r_{xi} [mm] radius of curvature in meridian direction	y, z coordinates of vertex		tilt angle in generatrix direction	
i=1	∞		(0、0)		0	
2	-3752.581	-50.580	(2.85、23.13)	AAL	0	in prism
3	-66.938	-38.651	(36.37、34.72)	AAL	14.15	in prism
4	-3752.581	-50.580	(2.85、23.13)	AAL	0	in prism
5	306.125	1095.447	(18.59、31.48)	AAL	69.84	in prism
6	∞		(21.46、32.54)		51.20	

(AAL2、4)	$K_{y2、4}$	$K_{x2、4}$	$AR_{2、4}$	$BR_{2、4}$	$CR_{2、4}$	$DR_{2、4}$
	-33820.5	-11.350	-0.144E-4	0.398E-7	-0.153E-9	0.201E-12
			$AP_{2、4}$	$BP_{2、4}$	$CP_{2、4}$	$DP_{2、4}$
			-0.152	0.730E-1	0.494E-1	0.255E-1
(AAL3)	K_{y3}	K_{x3}	AR_3	BR_3	CR_3	DR_4
	1.063	0.127	-0.225E-5	0.316E-8	-0.188E-11	0.474E-15
			AP_3	BP_3	CP_3	DP_3
			0.372	0.568E-1	-0.168E-1	-0.208E-1
(AAL5)	K_{y5}	K_{x5}	AR_5	BR_5	CR_5	DR_5
	745.334	-651374	-0.656E-6	0.124E-6	0.474E-12	-0.972E-11
			AP_5	BP_5	CP_5	DP_5
			0.837E1	-0.273	0.563E1	-0.538

refractive index (d-line) of prism 1.49171

focal length in generatrix direction f_y=23.09mm

Abbe's number (d-line) of prism 57.4

focal length in meridian direction f_x=23.09mm

(numerical data)

α = 0°	$2f_x/r_{x2}$ = -0.91	$2f_y/r_{y3}$ = -0.69
$\lvert f_y/f_x \rvert$ = 1.0	$2f_x/r_{x3}$ = -1.19	E = 33.5mm
$\lvert r_x/r_y \rvert$ = 0.58	$2f_y/r_{y2}$ = -0.01	γ = 1.52°
		β = 18.6°

[0048]

[Effect of the Invention]

As explained in the foregoing, the present invention provides a spectacle-type display having a wide viewing angle (high magnification) of ±16.8° in the horizontal direction and ±11.4° in the vertical direction, and an extremely small thickness of 10 to 15 mm in the direction parallel to the optical axis of the eye. It also provides satisfactorily bright optical performance. Furthermore, by constituting the concave mirror with a half-transmitting surface, it is rendered possible to superimpose a bright virtual image of the original image with the scenery without distortion.

[0049]

The foregoing embodiment has been designed to obtain a wide viewing angle, but the thickness may be made even smaller if a somewhat narrower viewing angle is selected, since the thickness according to the present invention is variable depending on the viewing angle.

[Brief Description of the Drawings]

[Fig. 1]

Views showing optical paths in the observation optical system of the present invention.

[Fig. 2]

Views showing a cross section and optical paths in the observation optical system of a numerical example 1 of the present invention.

[Fig. 3]

Views showing a cross section and optical paths in the observation optical system of a numerical example 2 of the present invention.

[Fig. 4]

Views showing a cross section and optical paths in the observation optical system of a numerical example 3 of the present invention.

[Fig. 5]

Views showing a cross section and optical paths in the observation optical system of a numerical example 4 of the present invention.

[Fig. 6]

An optical cross-sectional view showing the basic principle of the observation optical system of the present invention.

[Fig. 7]

An optical cross-sectional view showing the basic principle of the observation optical system of the present invention.

[Description of Reference Numerals or Symbols]

1 ... Total reflection surface (or transmitting surface)

2 ... Concave mirror

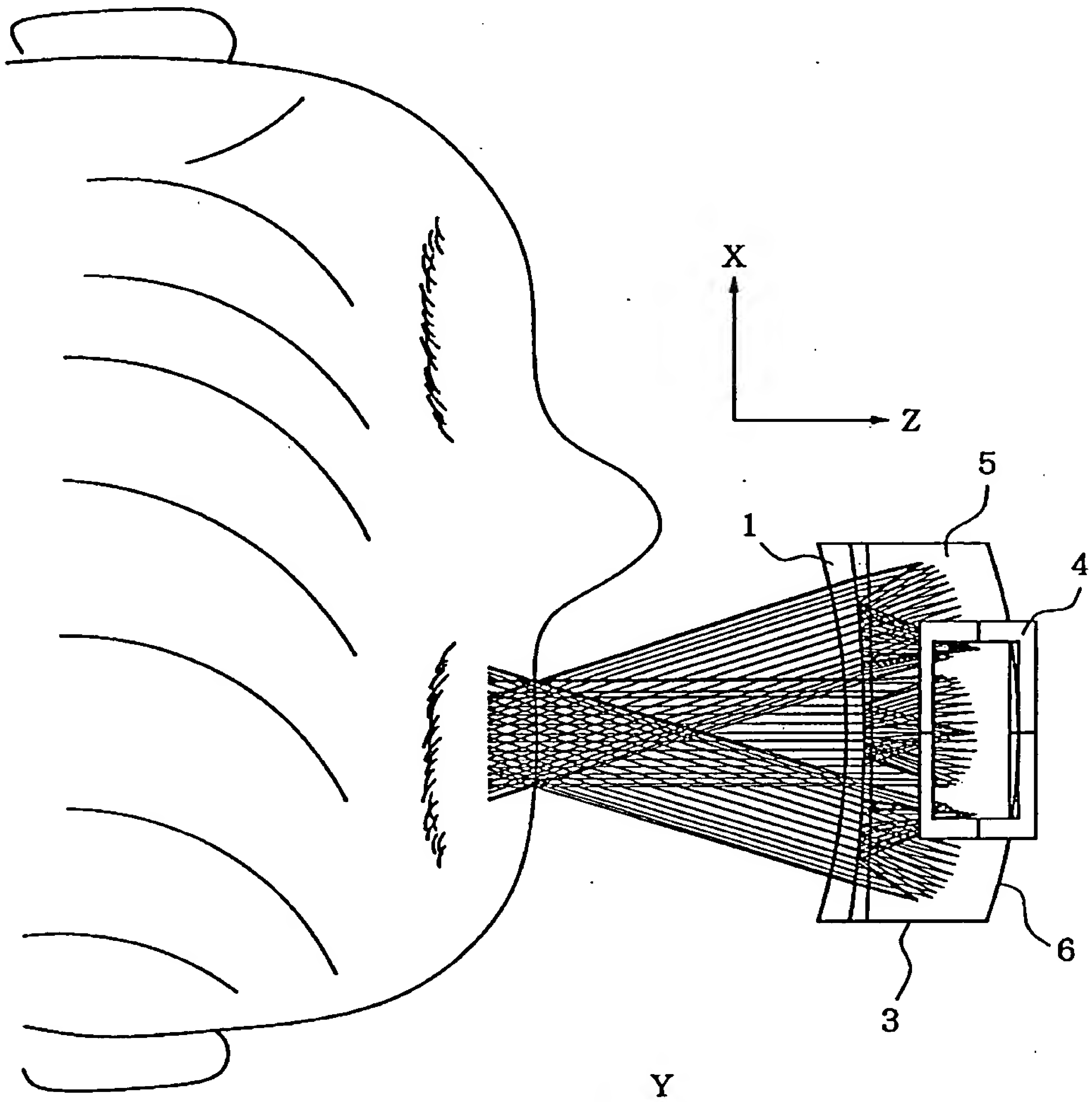
5 ... Entrance face

4 ... Display means for forming an original image

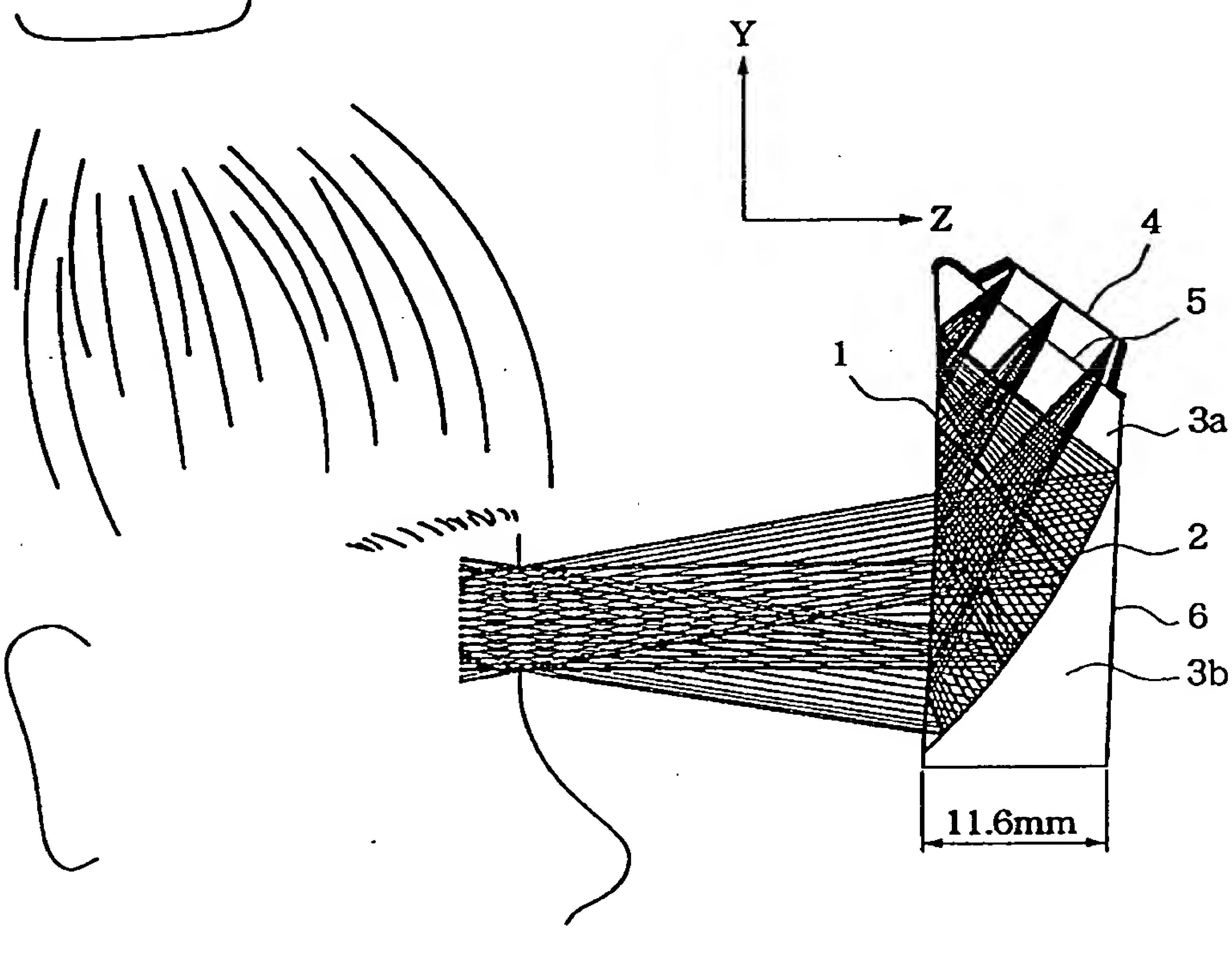
【書類名】　図面　[Name of the Document] Drawings

【図１】 Fig. 1

(A)

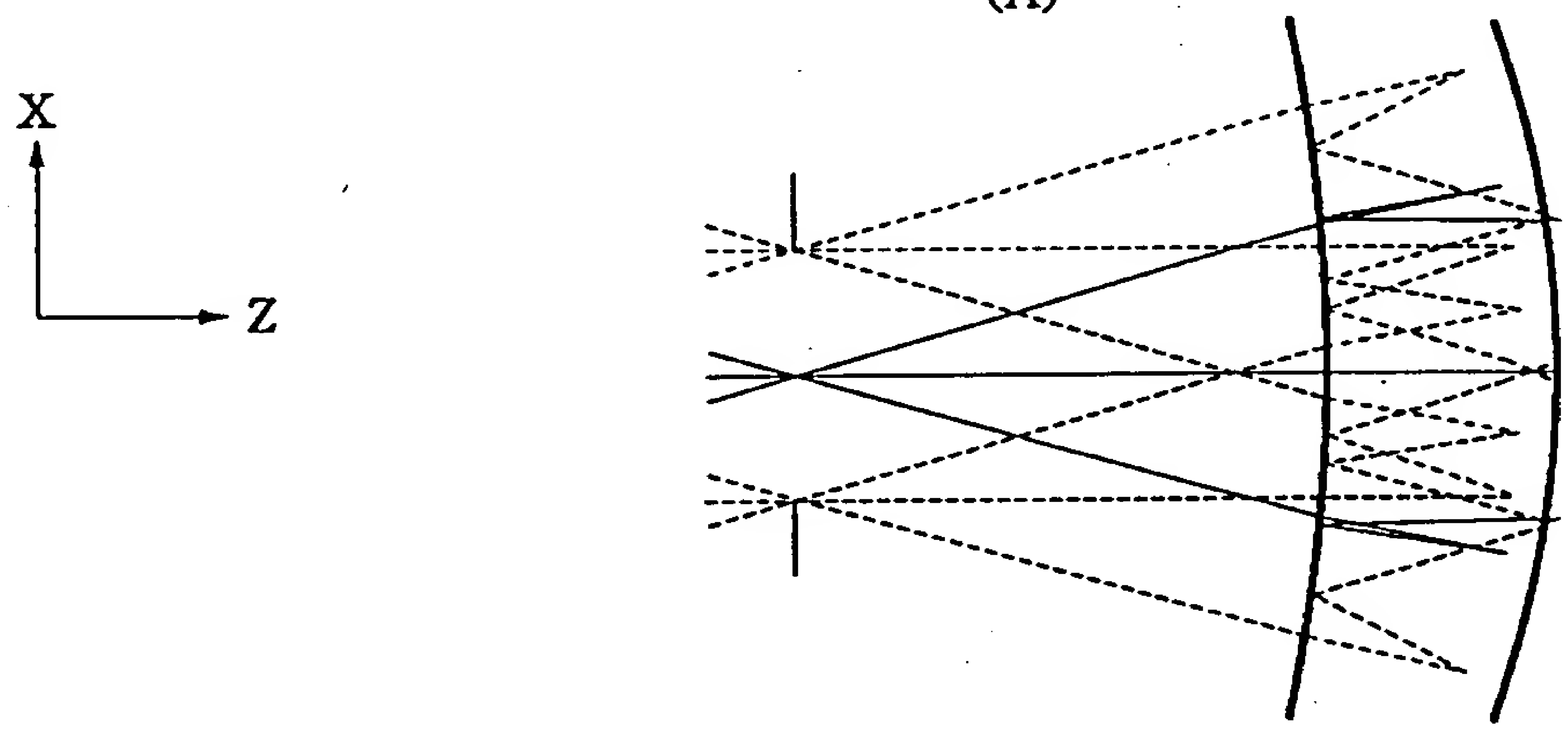


(B)

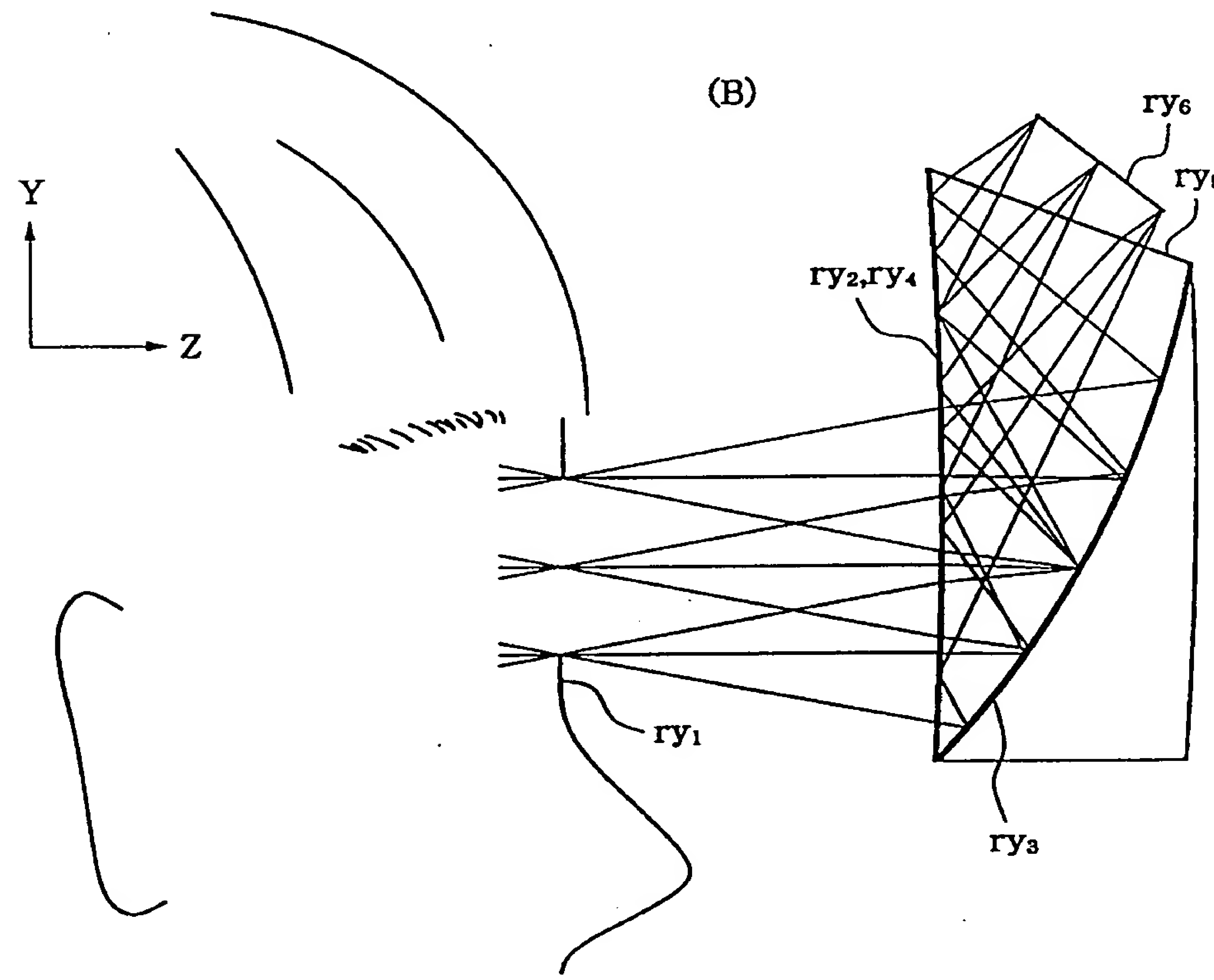


【図２】 Fig. 2

(A)

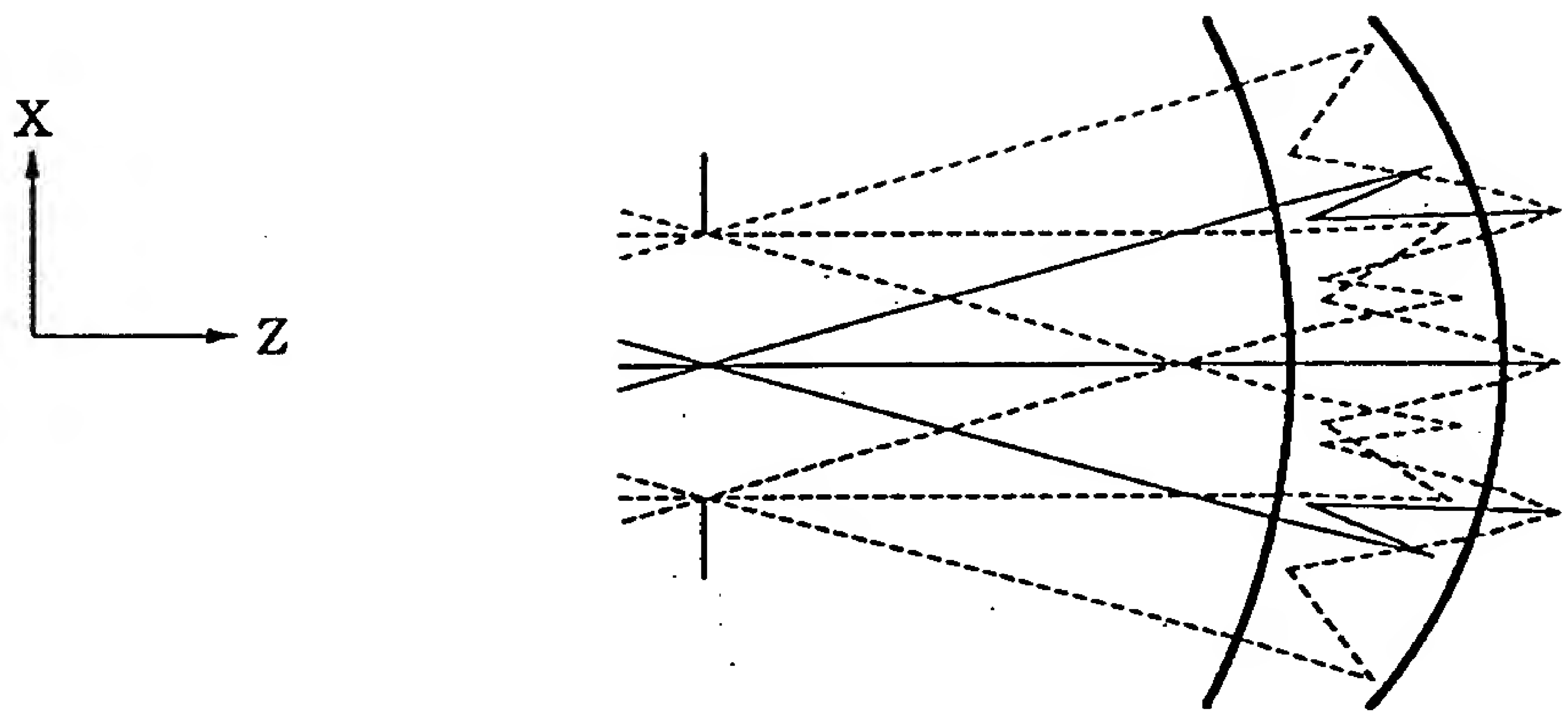


(B)

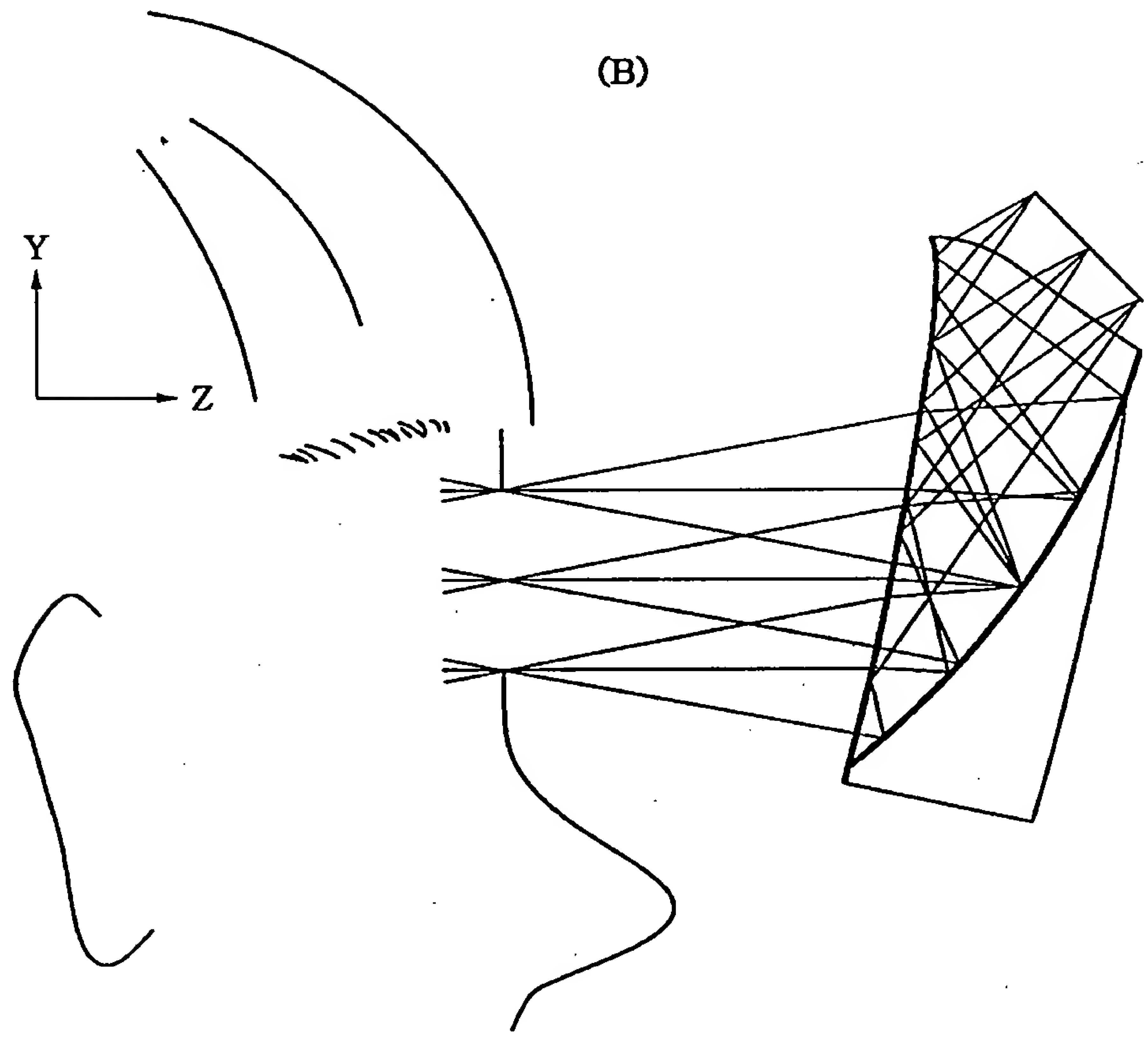


【図３】 Fig. 3

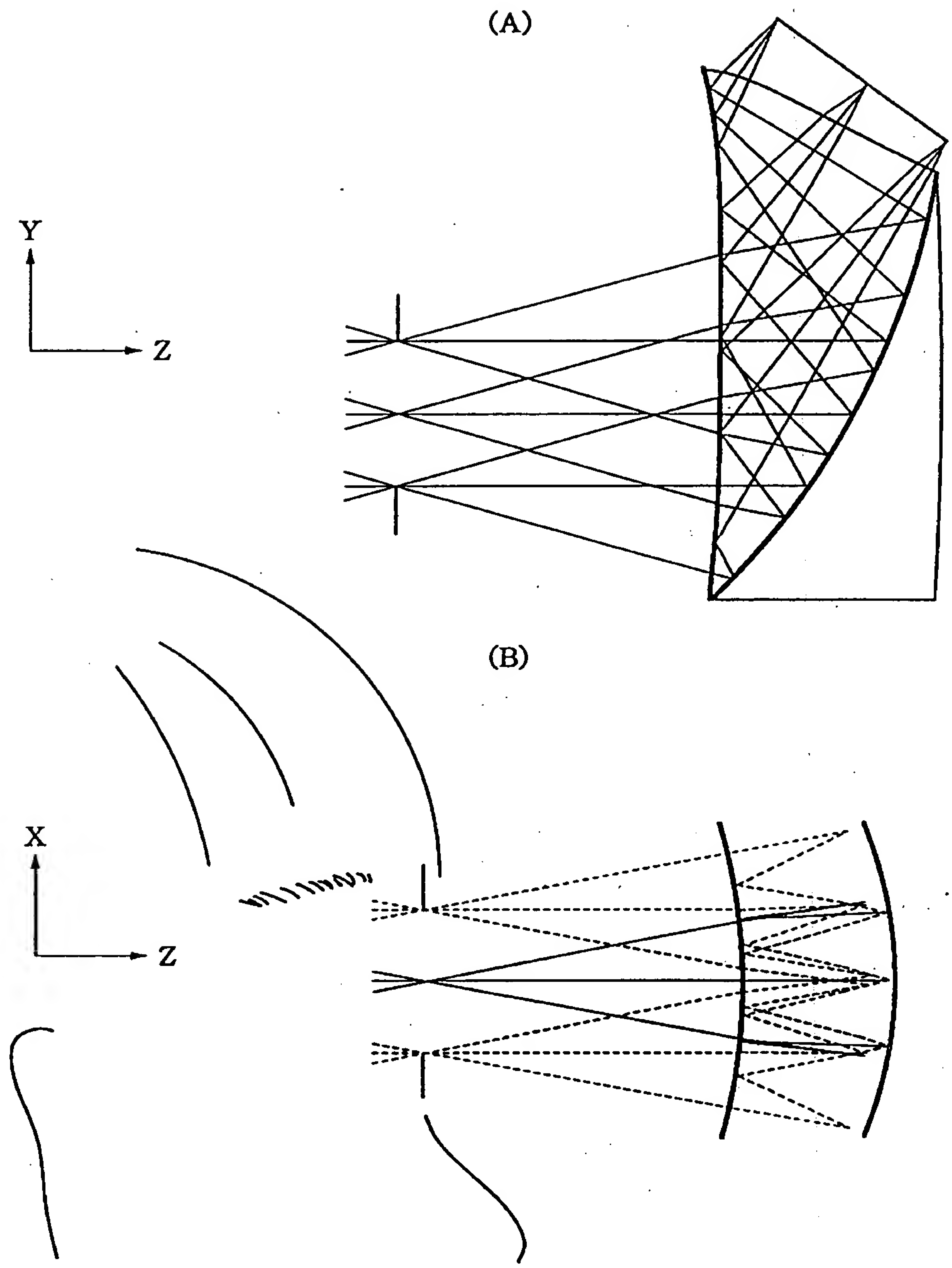
(A)



(B)

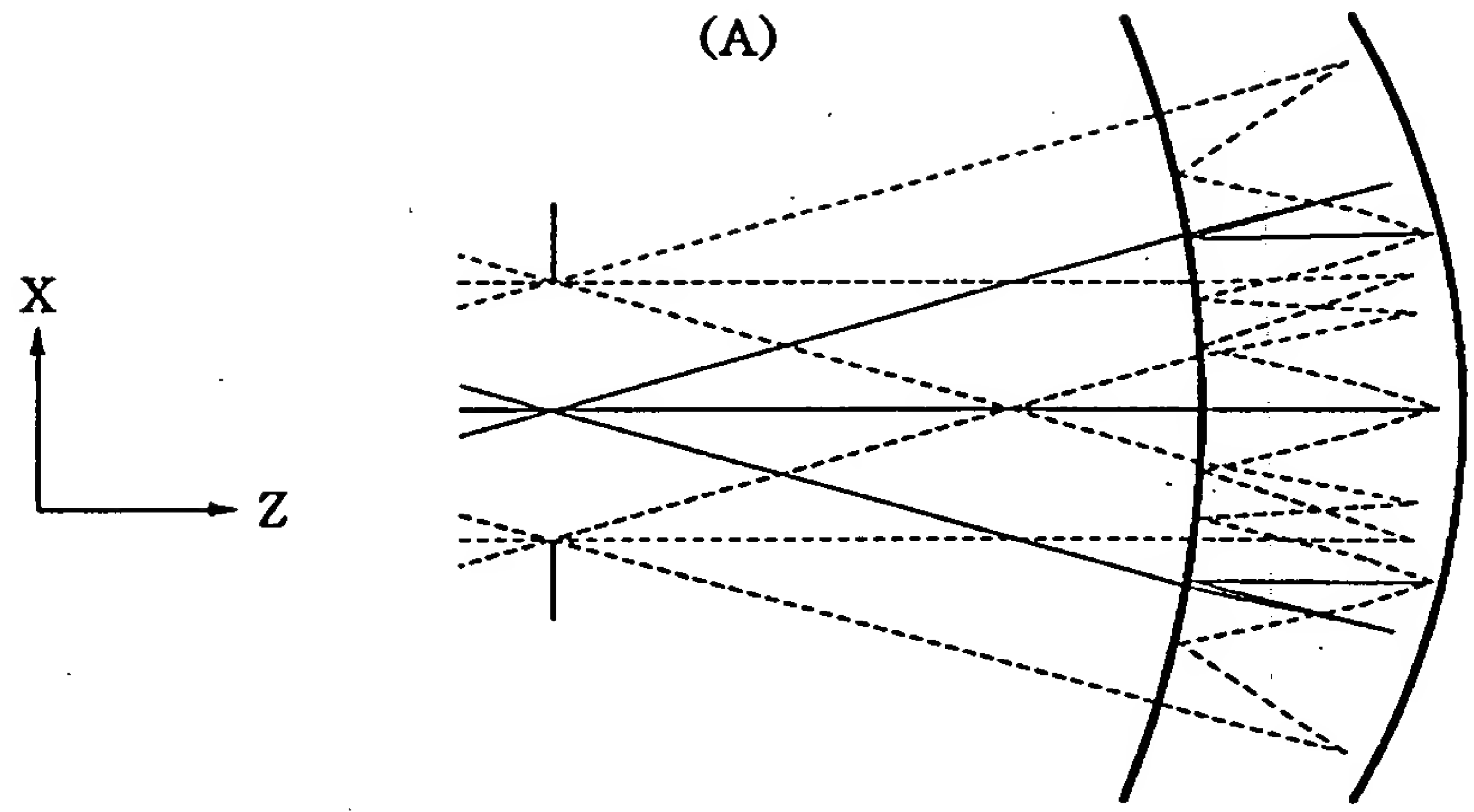


【図４】 Fig. 4

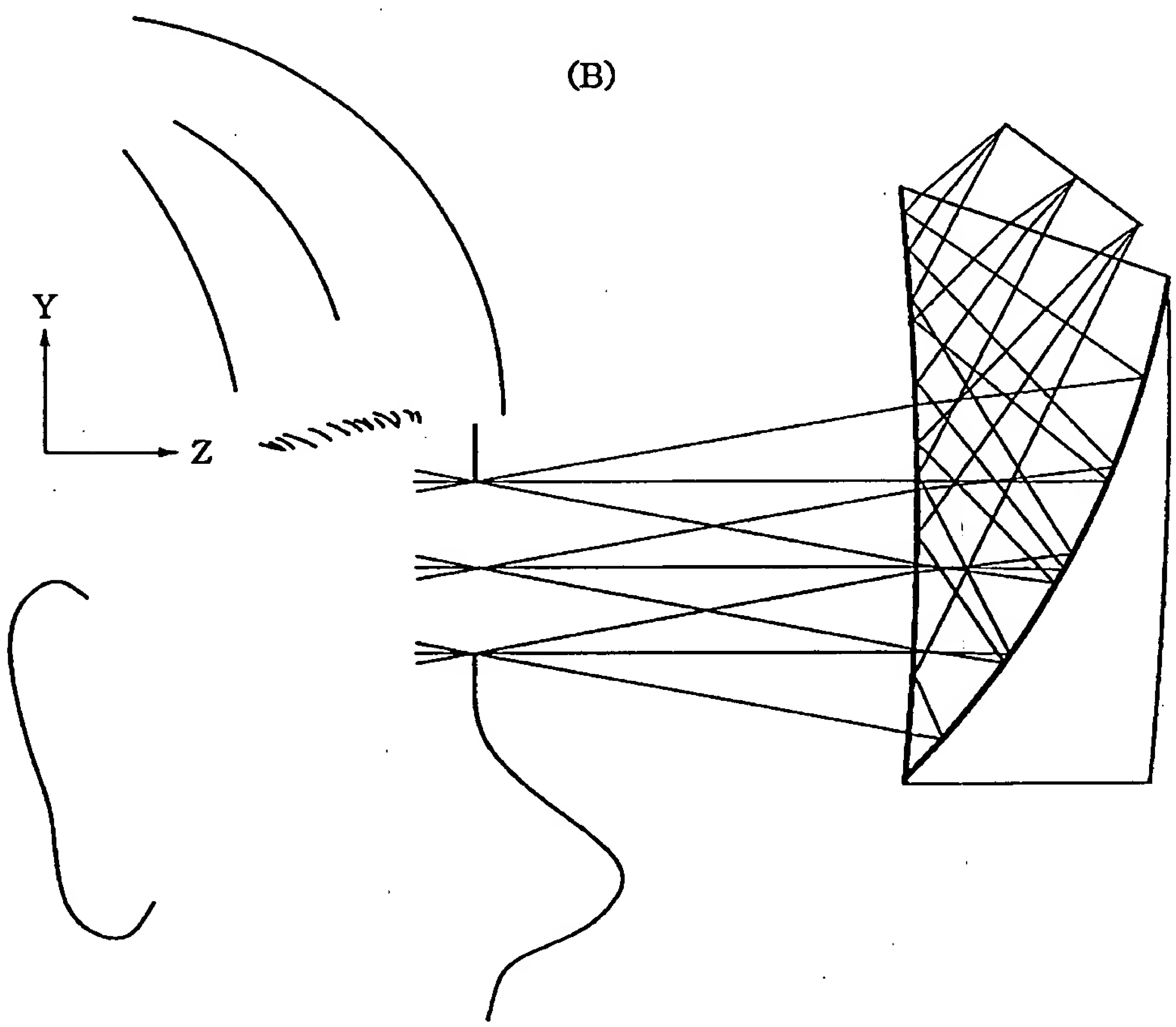


【図５】 Fig. 5

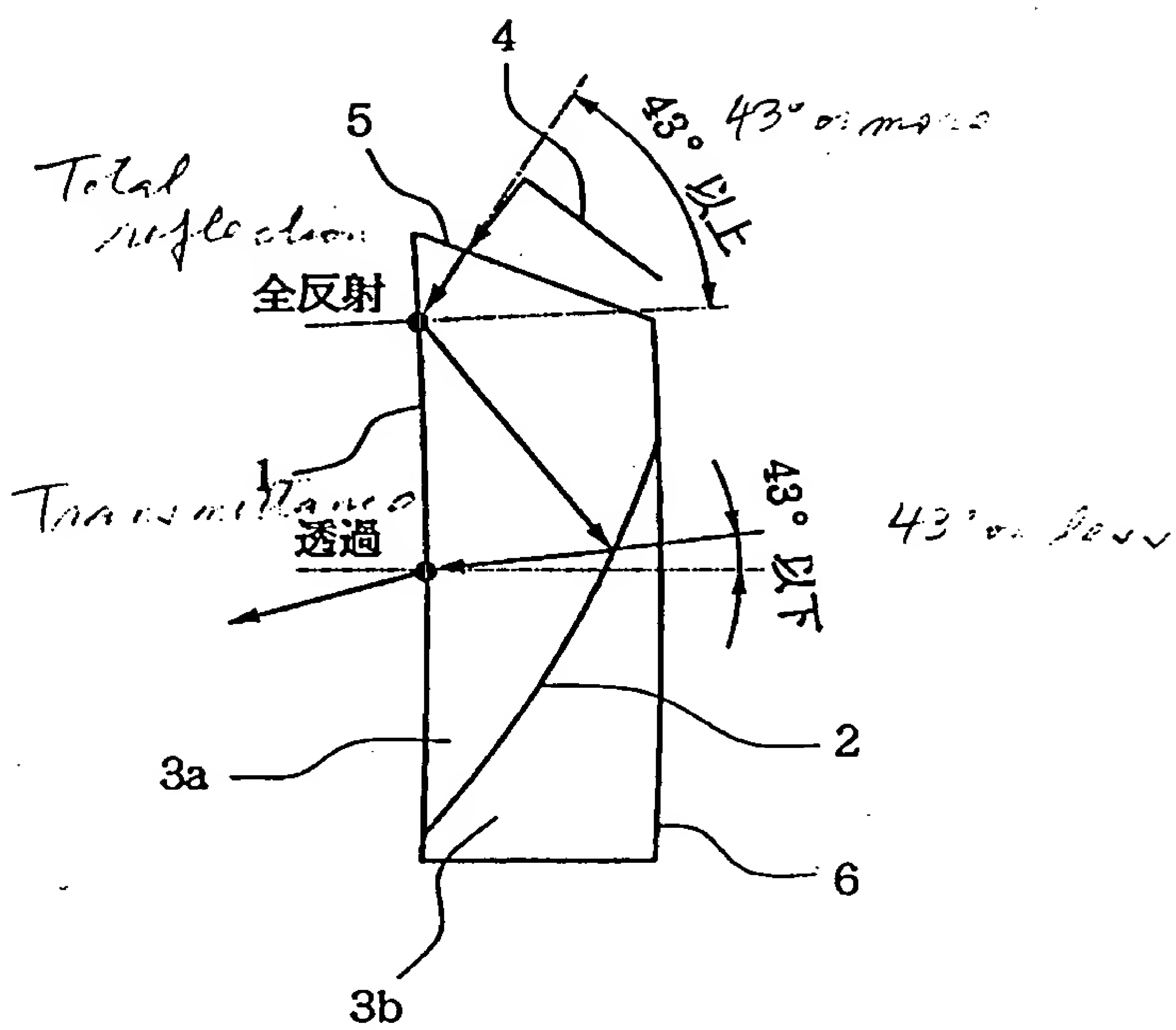
(A)



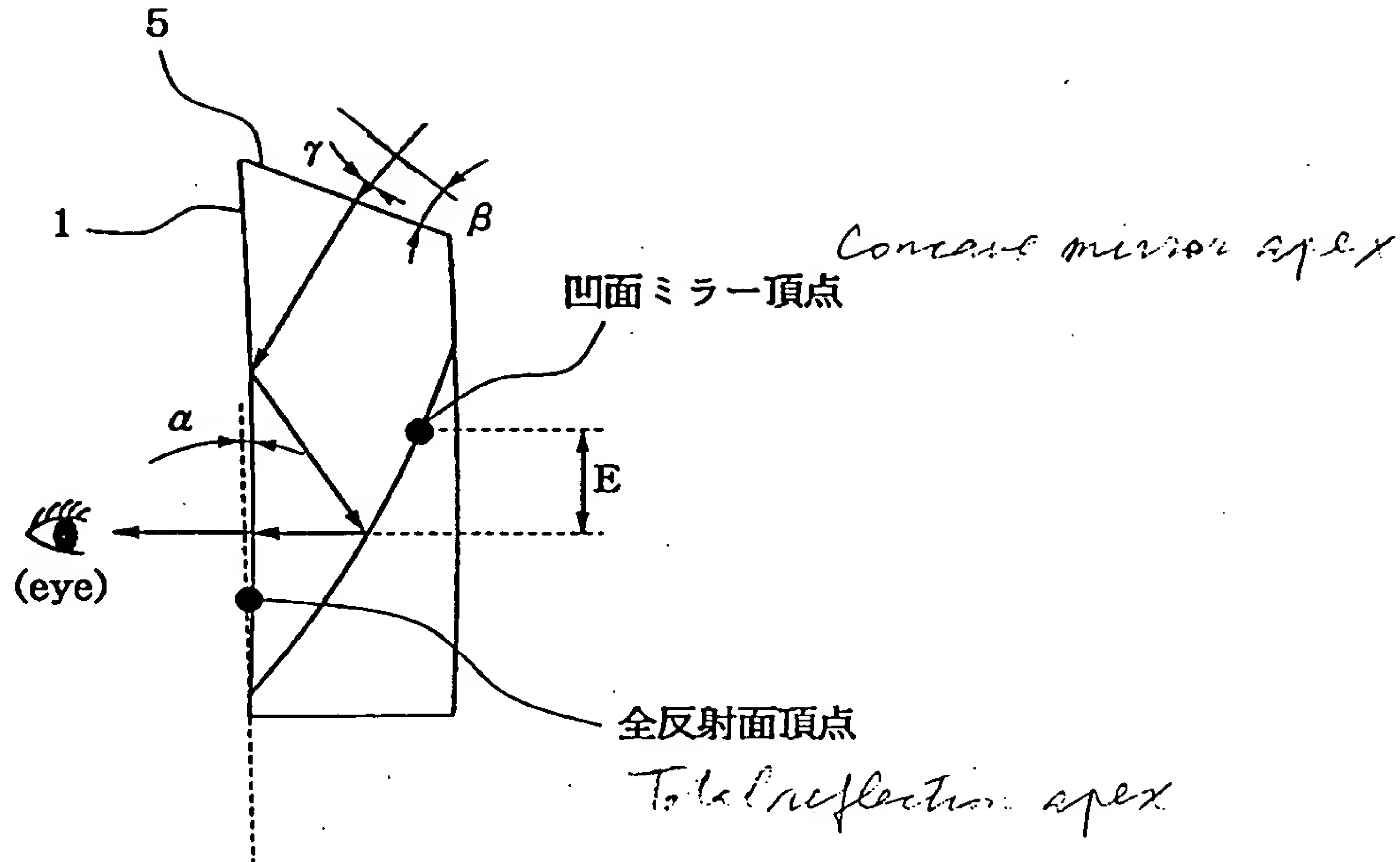
(B)



【図６】 Fig. 6


4
5
Total reflection
全反射
43° 以上
43° or more
1
Transmittance
透過
43° 以下
43° or less
2
3a
6
3b

【図７】 Fig. 7


5
1
γ
β
Concave mirror apex
凹面ミラー頂点
α
E
(eye)
全反射面頂点
Total reflection apex

[Name of the Document] Abstract

[Abstract]

[Object] An object of the present invention is to provide a compact and thin observation optical system for guiding an original image such as LCD to the eye of the observer.

[Constitution] In an observation optical system for guiding the light of an original image to the eye of the observer, the light is totally reflected at a curved surface in a direction away from the eye, this totally reflected light is reflected at a reflecting surface, particularly at a reflecting surface having a variable optical power depending on the azimuthal angle, and is transmitted through the curved surface to be guided to the eye of the observer.

[Elected Drawing] Fig. 1